Digital TV Team

Capturing the Full Potential Of Digital Television

April 7, 1997

COMPAQ intel® Microsoft

CAPTURING THE FULL POTENTIAL OF DIGITAL TV

Introduction

Immutable forces are propelling the TV industry toward a new, digital era. The recent FCC endorsement of a cross-industry agreement on advanced TV standards, the government's licensing this week of new digital broadcast channels for television stations, and the impending convergence of TV and computing technologies all foretell dramatic changes in the very near future. These changes provide the TV industry with significant opportunity.

But the TV industry's ability to reach the full potential of this opportunity will depend greatly on the industry's upcoming decision regarding video display formats. The industry will need to commit to one of two paths: (1) an approach being advocated by some traditional TV manufacturers; or (2) an approach from a DTV team of Compaq, Microsoft and Intel of the computer industry (the "Digital TV team")[1]. This decision will dramatically affect the economic future of the TV industry and its role in leading digital convergence.

This paper is the first in a series of white papers that will compare the two alternatives and communicate the DTV team's vision of the future. The paper has two parts: (1) a business and economic evaluation of the two approaches; and (2) an overview of the DTV team's technical proposal for migrating to digital television. In the first section, we describe the opportunity to create more compelling, interactive entertainment and information services with progressive DTV standards. We show how the computer industry approach requires a lower total investment for broadcasters, uniquely opens a broader range of new revenue opportunities, and results in larger audiences for digital broadcast services. In the second section, we outline a technical approach proposed by Compaq, Microsoft and Intel that will best meet the objectives of the TV industry and the needs of viewers. In summary, this paper provides the roadmap toward capturing the full potential of digital television.

Sea Change in Television Industry

The TV industry is undergoing unprecedented change. A new regulatory environment, changing customer interests, new technologies and the Internet are all contributing to a new era for television. The FCC order last December marked a departure from traditional practices, agreeing with a cross-industry agreement that market forces, not government mandates, should determine the new standards for digital video display formats. The FCC's recent decision creating mandatory implementation schedules for digital television explicitly requires broadcasters to begin their conversion to digital in the very near future. Clearly the government's actions support the advent of a new, wide-open, market-driven digital world.

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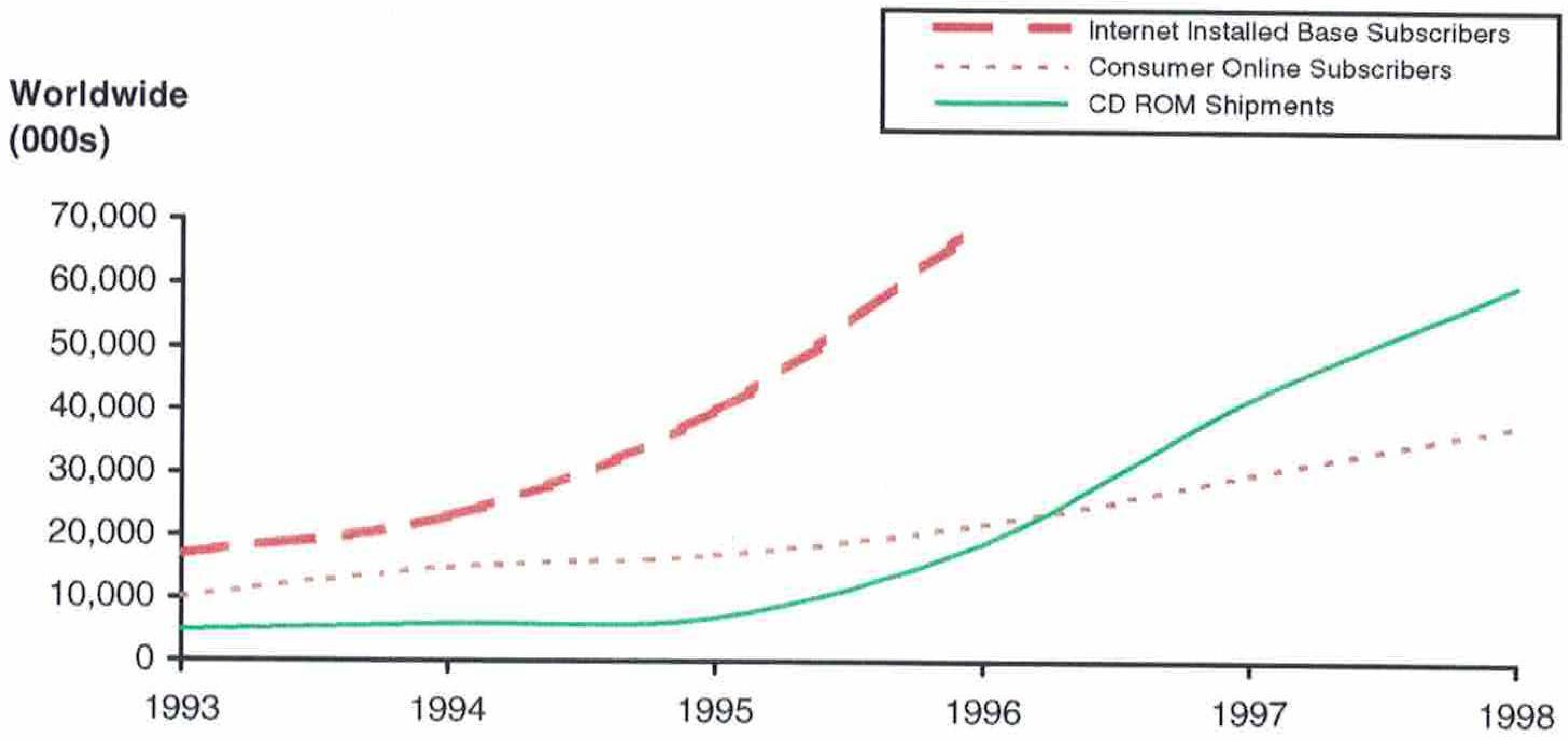
[1] Digital TV team currently consists of Compaq, Microsoft and Intel; the team will likely expand over time as other companies have expressed an interest in joining.

Additionally, the explosion of the use of PCs for the Internet and multimedia has inspired a demand for new forms of entertainment. The graph below illustrates the exponential growth in the installed base of the Internet, subscribers to online services and CD ROM shipments.



Source: IDC, EIA

Figure 1: Growth of Internet and Multimedia

This growth will continue. Census Bureau data shows that 98% of all elementary and secondary students in the U.S. today are using a computer at school, home or in both places. Additionally, Forrester Research estimates that by the year 2005, 77% of all workers in the U.S. will be using a PC.

This growth highlights a fundamental change in the types of viewing and entertainment experiences people are growing to expect. It marks a shift from passive, one-way entertainment to interactive, multimedia with a broad combination of entertainment, communications and information services. This is the future of entertainment: 85% of Internet users are under the age of 50; and the majority of PC users are upper income – the most attractive target for advertisers.[2] The marketplace has responded to the demand for new forms of entertainment with a proliferation of new products and services such as web TVs, TVs with Internet access, and PCs with TV tuners, to name a few. These products, new entertainment media and changing customer desires all confirm the inevitability of the convergence of computing and TV technologies, and the irrepressible nature of the sea change in the TV industry.

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[2] CEMA; Dataquest; Morgan Stanley Reports

TV Industry Direction

As the TV industry enters this new digital era, it will need to make a decision regarding video display formats. There are two directions the industry can take: one advocated by some traditional TV manufacturers and the other supported by the Digital TV team. The traditional TV manufacturers propose implementing the full 18 formats of the ATSC specification including the 1080 line high resolution format utilizing interlace ("i") scanning. The Digital TV Team advocates an approach adopting a practical subset of the full ATSC specification, utilizing progressive ("p") scan transmission and offering standard and high-definition resolutions.[3] Under this plan the television industry could migrate to higher resolutions (e.g., 1080p and higher) employing a layered strategy when cost effective in the future.

This decision on video display formats is critical. As part of the transition to digital broadcasting, the industry must make substantial investments in production and transmission equipment that will effectively commit them to either interlace or progressive scanning for a long time. Initial investments in this equipment will drive decisions in both upstream and downstream equipment, thereby creating a de facto standard that may not be easy to upgrade as more advanced and cost-effective technology becomes available. Additionally, the range of new media entertainment, communications and information services that broadcasters will be able to provide in the future differs significantly between these two approaches. The financial future and the TV industry's strategic position in the digital era will depend largely on this decision.

Assessing the Two Paths for TV Industry

The DTV team approach promises a far better future for the TV industry, primarily due to four key advantages: (1) progressive scan technology enables a bolder, more exciting vision of the future; (2) integrating broadcast with other digital computer media creates broad, new revenue opportunities; (3) the DTV team approach requires less investment by broadcasters and mitigates potential risks; and (4) the DTV approach will have faster penetration of digital receivers in the home, ensuring larger audiences for digital broadcasts.

1. Vision of the Future

The two approaches provide very distinct visions of the future. The Digital TV team approach promises the highest quality video images combined with emerging Internet and Web-based applications. It enables crisp images for the broadest range of multimedia content, including text, pictures, graphics and 3D video, seamlessly integrated with broadcast video. Viewers would receive the broadest possible range of compelling, interactive entertainment and information offerings.

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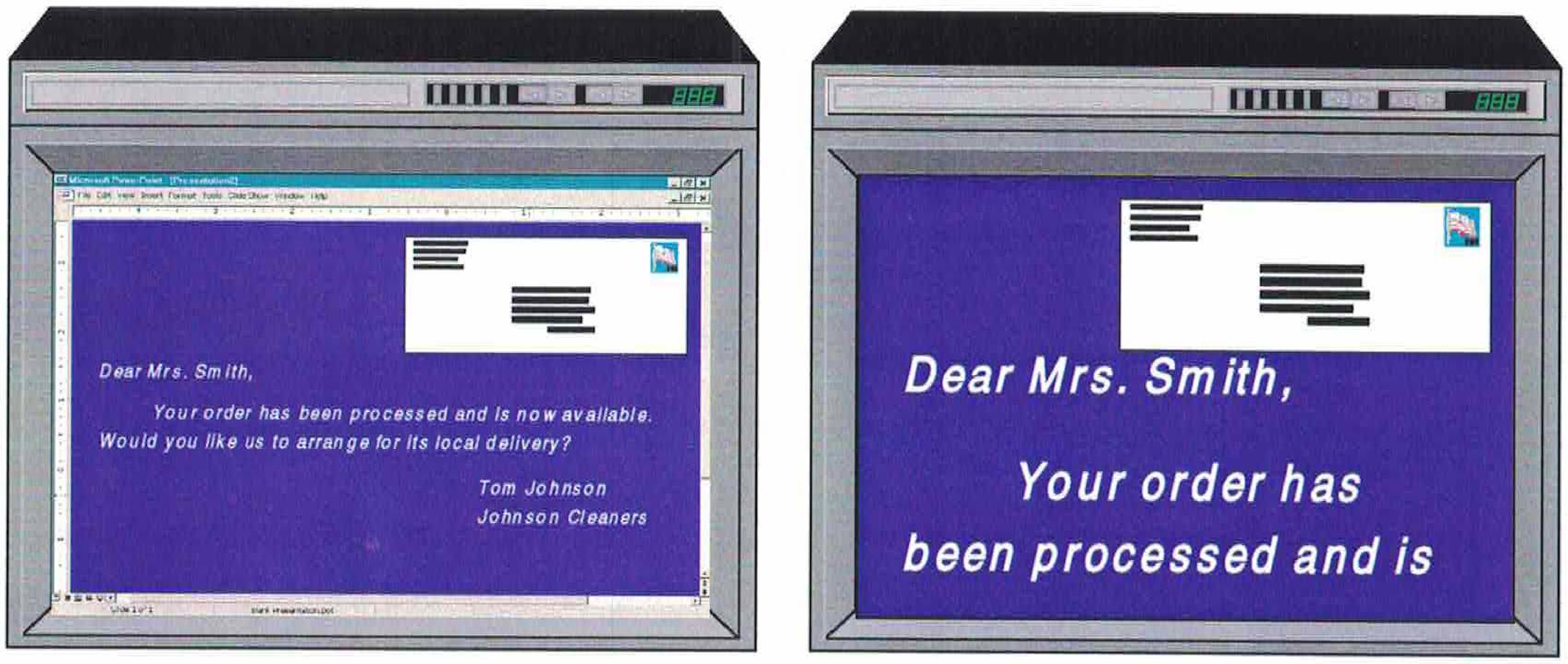
[3] Additional description of our technical approach is included in the second section of this paper.

The vision outlined above contrasts sharply with the future being promoted by some traditional TV manufacturers. Their approach relegates digital TV to merely receiving a digital broadcast signal with improved audio and higher definition video displayed on a big screen TV. Interlaced displays simply cannot support the same quality of high-resolution static graphic images as progressive scanning. Prime examples of this limitation appear in the emerging Internet TV appliances, such as WebTV. Because of the alternating nature of interlace scanned lines, static video objects, such as text, must be processed and converted, rather than simply displayed in their native electronic format. This limits the number of supported fonts and restricts capacity for displaying graphics images and photographs, as shown in Figure 2. With interlace formats, content authored for the Internet must be re-adapted, at considerable cost, for display in a television environment.



Dear Mrs. Smith,

Your order has been processed and is now available. Would you like us to arrange for its local delivery?

Tom Johnson
Johnson Cleaners

Dear Mrs. Smith,

Your order has been processed and is

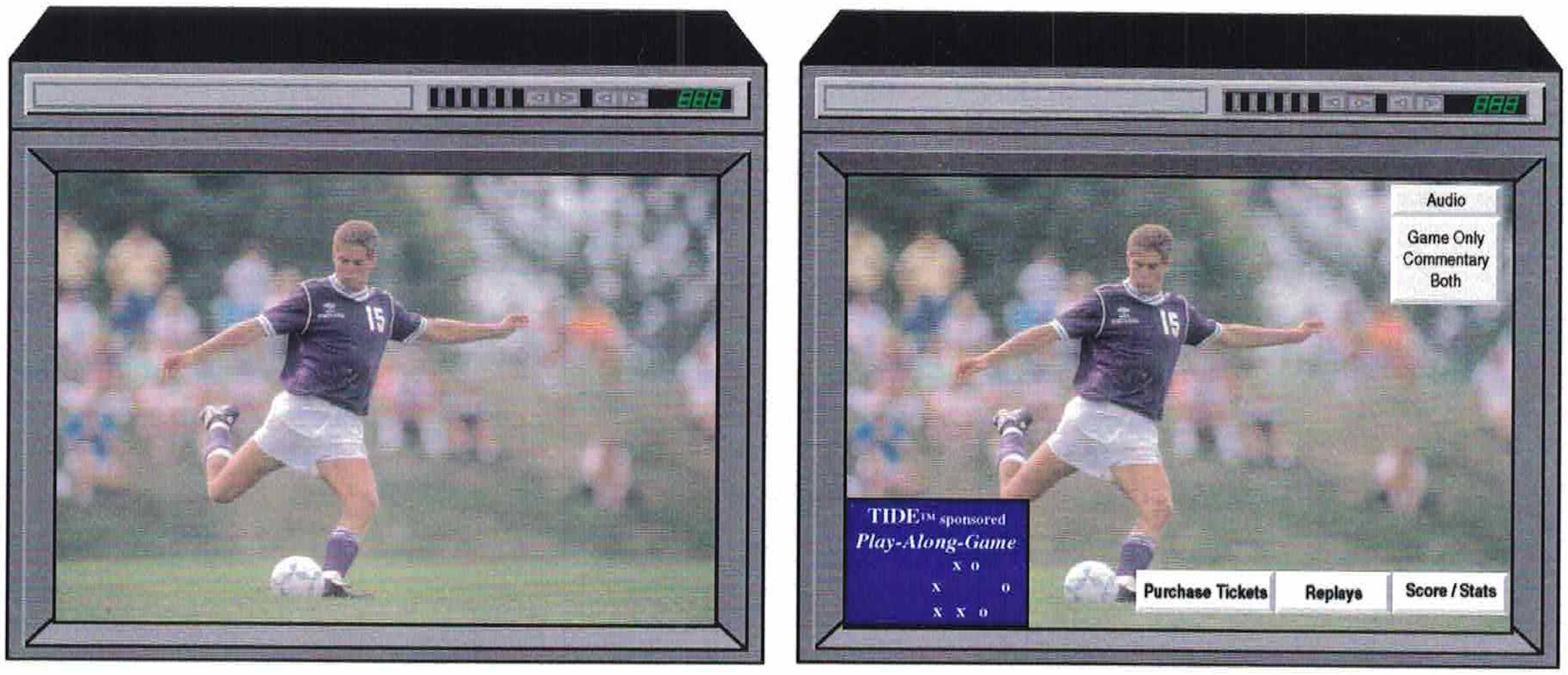
Progressive Scan *Interlace Scan*

Figure 2: Comparative Illustration of Progressive and Interlace Text and Graphics Images

2. New Revenue Opportunities

The bolder vision of the future supported by the Digital TV Team provides potentially large, new revenue opportunities for the television industry. At the least, a more engaging entertainment offering that creates a deeper, more personalized involvement will attract and retain additional viewers and corresponding advertising revenue. Television programming enhanced by data services can allow viewers to gain more information about the story, participate in "chat" with actors or other viewers, and provide feedback to the writers; all of these services will foster viewer loyalty. But perhaps even more promising are new revenue sources that can be generated from new innovative programming and electronic commerce.

Multimedia capabilities with progressive scanning allow the creation of broad new categories of programming. Figure 3 illustrates just one of many exciting opportunities for viewers. In this example, a sporting event is enhanced with multiple streams of video, audio and broadcast multimedia data. The viewer has the flexibility to select multiple broadcast enhancements which include: selecting multiple camera scenes; viewing play-by-play and simultaneous commentary; initiating instant replays of key events; checking game scores or player statistics; and/or playing a concurrent "play-along" game. The user control of the display objects creates a more engaging, interactive experience.

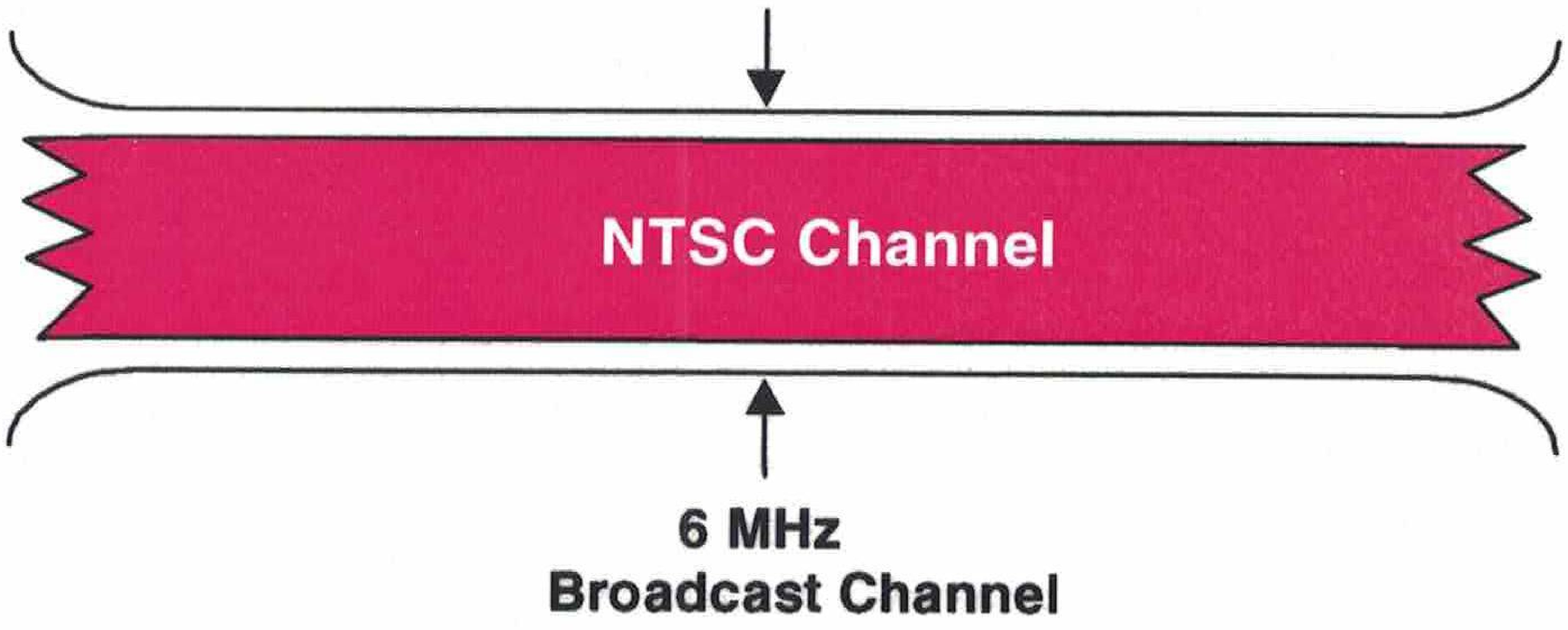


NTSC Broadcast Soccer

Potential DTV Broadcast Soccer

Figure 3: Example of Virtual Interactive Services Enabled With the Computer Industry's Progressive Scanned Video Formats

An illustration comparing the analog NTSC spectrum with the new digital spectrum (next page) shows how this will work. The multiple streams of video, audio and broadcast multimedia data objects, when digitally compressed, are multiplexed into the existing or new broadcasting channels. The user can control the display objects without the need for a return data path.



Current NTSC Broadcast Scheme

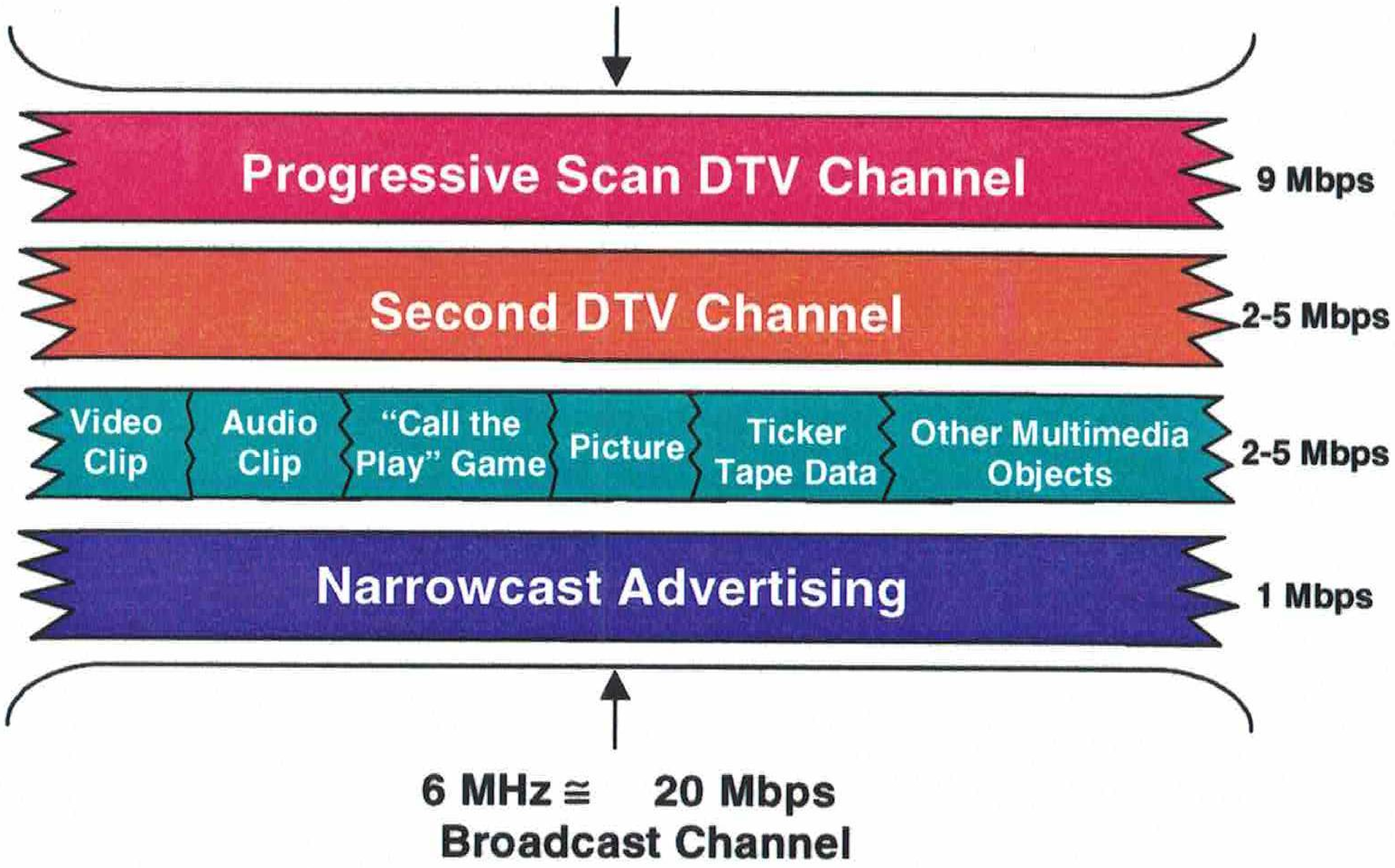
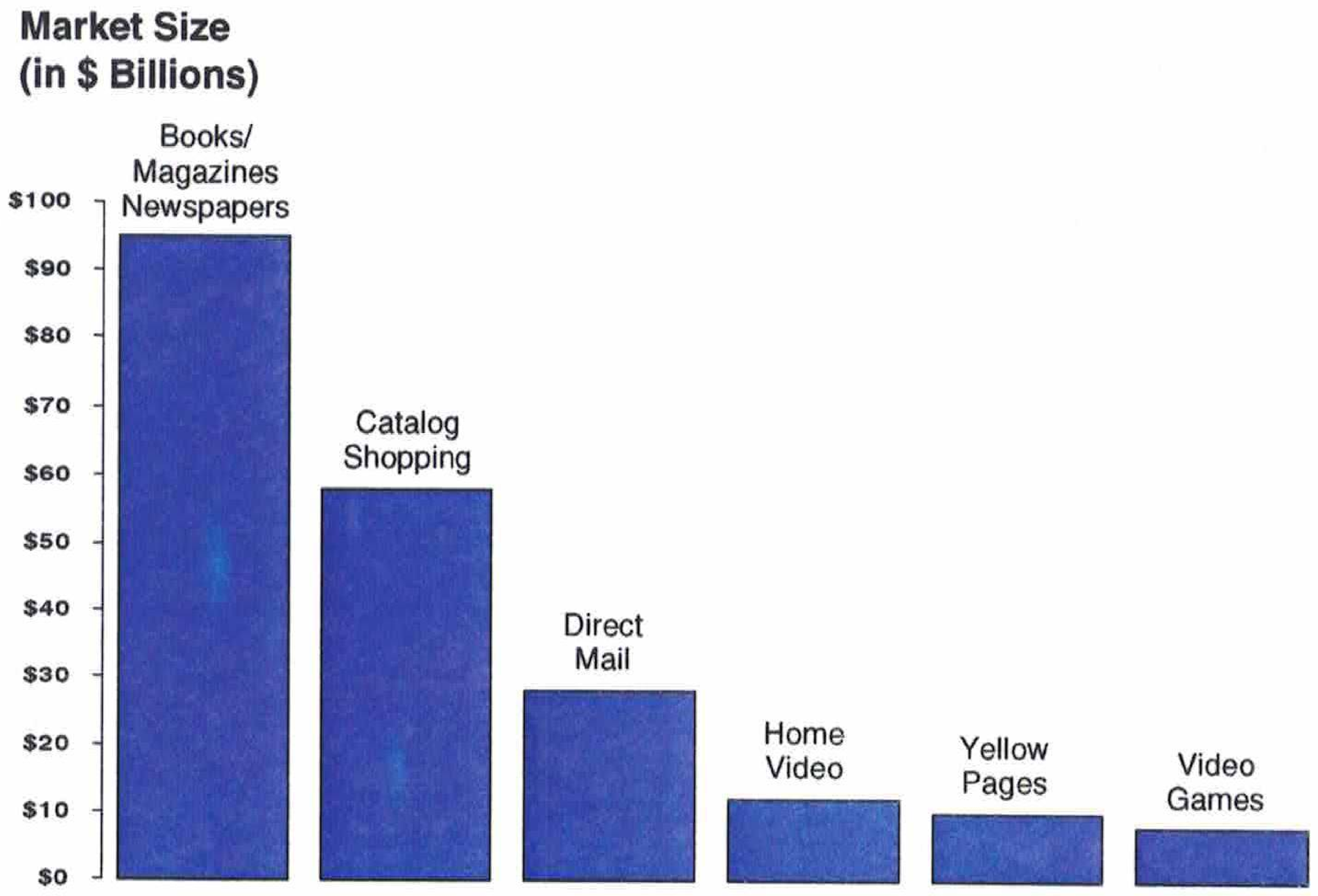


Figure 4: Conceptual Illustration of Broadcast Schemes with WWW Capability

Each of these broadcast enhancements potentially provide new sponsorship, advertising and/or subscription revenues. Interactive capabilities could be made available only to those who pay subscription fees. The replays and statistics would be ripe for corporate sponsorships. And the new, richer entertainment experiences will likely attract advertisers away from other media. As the multitude of new programming develops, broadcasters should be able to tap into lucrative new opportunities.

Equally large is the chance for the TV industry to participate in the growing market for electronic commerce. A fully interactive broadcast TV service enables direct and immediate viewer response, product ordering or surveying of market demand. Advertisers will benefit from capturing viewer feedback or even quickly closing a sale. Programmers and broadcasters will benefit from providing a more valuable advertising avenue and potentially capturing a share of transactional revenue that was previously not accessible.

The market potential for transactional revenues is enormous. As suggested by Figure 5, many existing product and service businesses are likely to be traded electronically in the future; the TV industry's commitment would only accelerate this new means of commerce.



Source: Bear Stearns, Salomon Brothers

Figure 5: Potential Electronically Delivered Home Services

Infrastructure for the interactive data connection, shown in Figure 6, already exists using the Internet and WWW. Two-way interactive data exchange, over the Internet, complements existing broadcast services by enabling direct and immediate ordering or service linked to broadcast signals. Network and local programming in the future will utilize broadcast as well as other Internet-based delivery services.

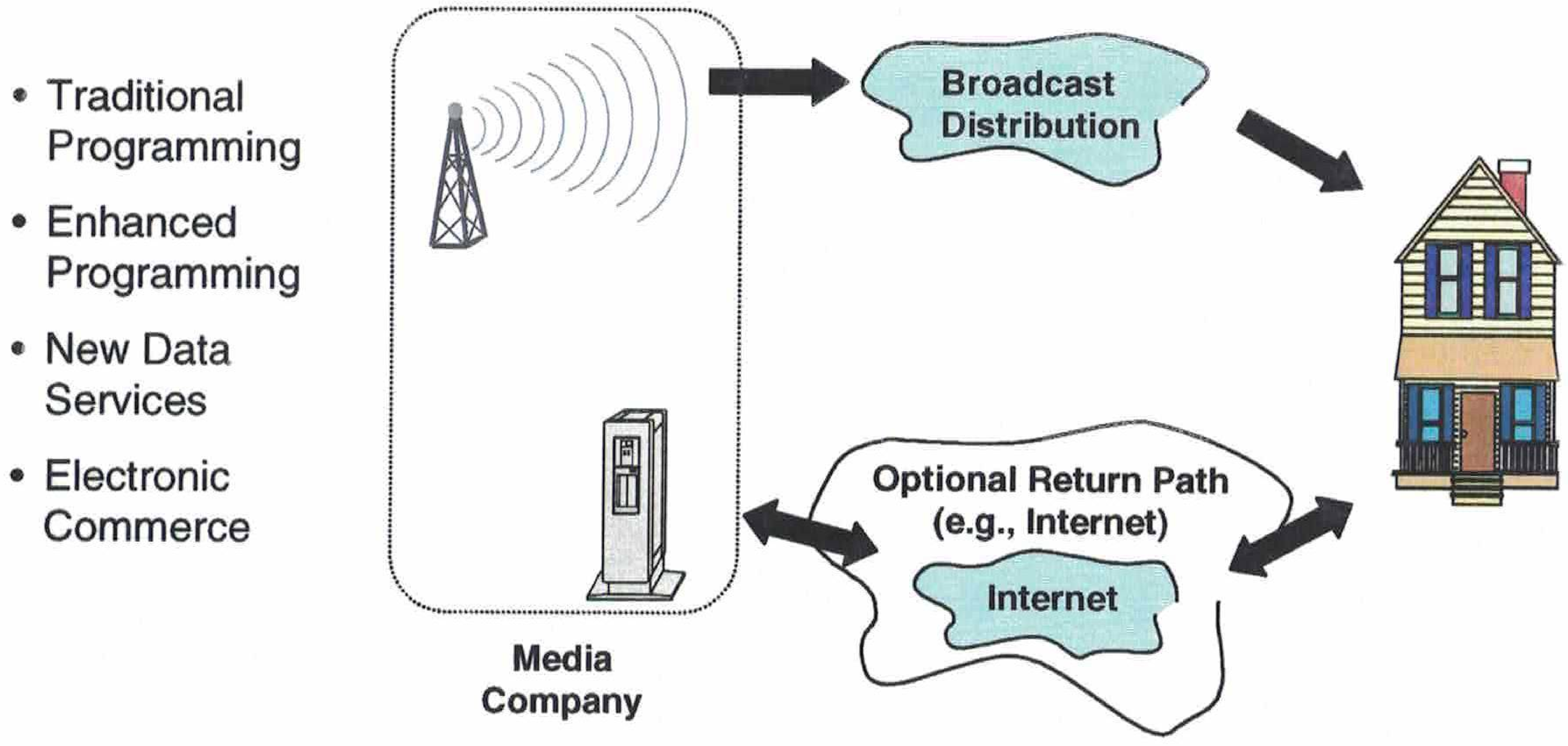
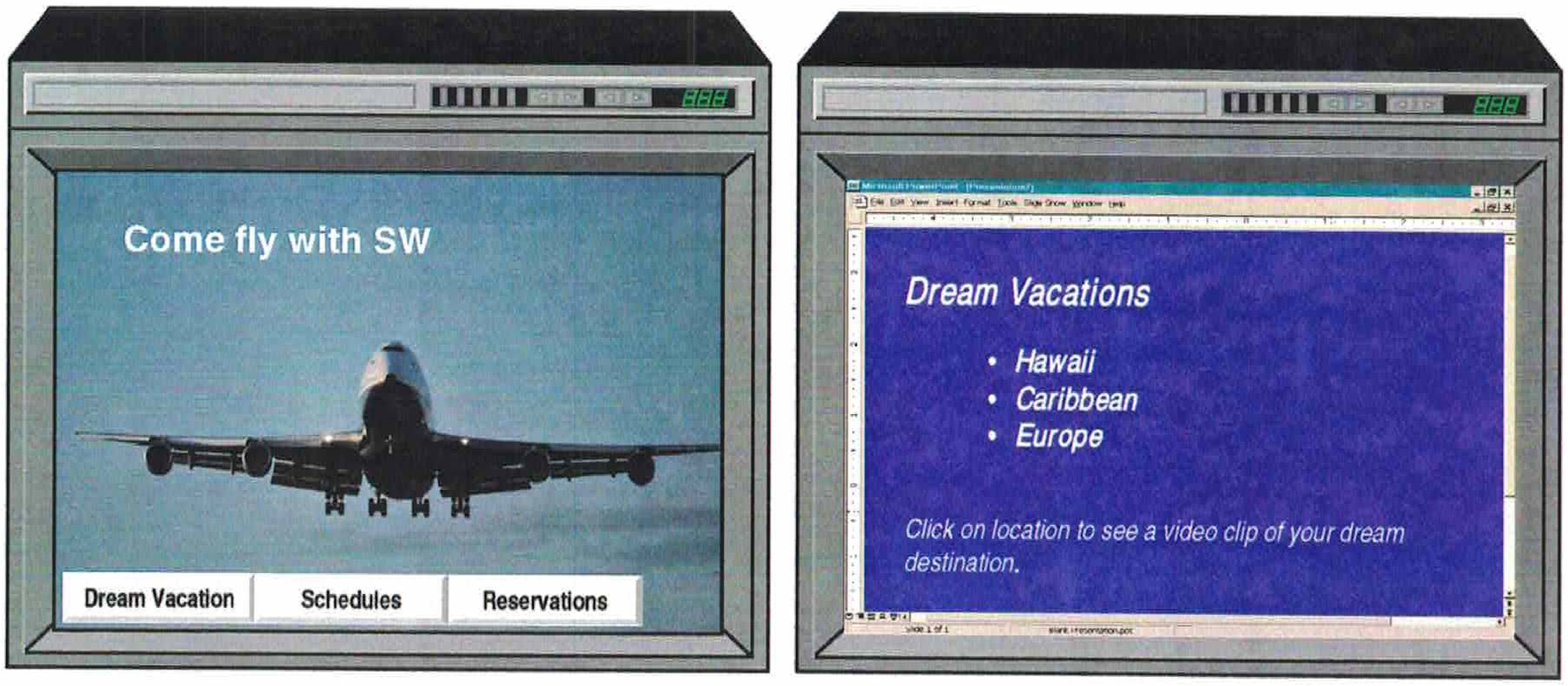


Figure 6: Example Implementation of Fully Interactive TV Service



Dream Vacations

- Hawaii
- Caribbean
- Europe

Click on location to see a video clip of your dream destination.

Figure 7: Example Interactive DTV Service

The diagram in figure 7 illustrates an example of the potential of electronic commerce. A viewer interested in getting more information or making a purchase after viewing a broadcast advertisement could immediately proceed using an Internet-based return path to the media company. In this example, the user could inquire about special airfares and destinations or enter a sweepstakes for a special ticket. Manufacturers and distributors might also purchase this information as qualified leads for their sales purposes. In this manner, the broadcast program originator can use the WWW as a vehicle for generating new transactional revenue tied to consumer purchasing.

The above examples of new programming and electronic commerce are small illustrations of the new growth available to the TV industry. The size of these opportunities magnifies the critical nature of the industry's decision on video display formats. The industry can only generate these revenues with a DTV format that is compatible with the WWW and Internet infrastructure and capable of mixing broadcast video and Internet content.

3. Lower Investment and Less Risk

The capital commitment, timing, and overall risks of the two plans are markedly different. The Digital TV team approach allows broadcasters to convert to digital in a less costly, time-phased and more strategic manner. The TV manufacturers' plan requires immediate, substantial capital outlays which leave broadcasters vulnerable to technology changes in the future.

The difference in initial capital outlays is driven primarily by the number of video formats that the TV industry will be required to support. The TV manufacturers advocate supporting 18 different video transmission formats; the DTV team initially supports a subset of these, with a migration path to supporting higher resolutions (including 1080 progressive) and enhancements in the future. The TV manufacturers' formats are listed below.

Vertical Lines	Pixels	Aspect Ratio	Picture Rate
1080	1920	16:9	60I, 30P, 24P
720	1280	16:9	60P, 30P, 24P
480	704	16:9 and 4:3	60P, 60I, 30P, 24P
480	640	4:3	60P, 60I, 30P, 24P

Table 1: Traditional TV Manufacturer's Proposed DTV Formats
(I = Interlace Scan, P = Progressive Scan)

A broadcaster compliant with the traditional TV manufacturer's proposal would need to purchase production and broadcasting equipment capable of handling the most computation and memory intensive (highest resolution) of these video formats to ensure a future ability to broadcast in any one of these 18 formats.

The computer industry has selected a practical subset of the 18 formats of the ATSC specification, as shown below. The plan suggests starting at 480x740x60p and gradually migrating to higher resolutions over time.

Vertical Lines	Horizontal	Aspect Ratio	Picture Rate
720	1280	16:9	24P
480	704	4:3, 16:9	60P, 60I, 24P, 30P

Table 2: Computer Industry Proposed DTV Formats

This subset of the ATSC formats allows programmers and broadcasters to be compatible with both the computer industry and traditional TV manufacturers' proposals. Moreover, viewers will still reap the full benefits of a digital image: progressive scanning modes at these resolutions provide far superior high-definition images than both the current NTSC formats and the proposed equivalent resolution interlace formats, as shown below.

Format	Visual Equivalent Format
480 Lines, 60 Frames/Sec, Progressive	720 Lines, 60 Frames/Sec, Interlace
720 Lines, 24 Frames/Sec, Progressive	1080 Lines, 24 Frames/Sec, Interlace

Table 3: Effective Viewing Equivalent of Computer Industry DTV Formats

Another critical issue is the timing of the above upgrade. The TV manufacturers' proposal requires the entire commitment of the above capital at one time. The computer industry recommends a gradual upgrade process, which initially provides higher definition TV, but defers the investment to attain the highest resolutions.

The gradual migration provides key benefits. First, it allows broadcasters to move at a more strategic pace. By rapidly deploying a base-level digital progressive signal, broadcasters can begin capturing incremental revenues to support the additional investment in higher resolutions. Also, the current lack of installed consumer reception equipment simply does not support investing in the highest resolution today.

Second, a time-phased upgrade will likely reduce the overall investment required due to Moore's Law. This law, illustrated in the graph below, indicates that digital signal processing and memory capabilities double every 18 months without an increase in cost. Deferring the upgrade to future higher resolution DTV formats capitalizes on this phenomenon.

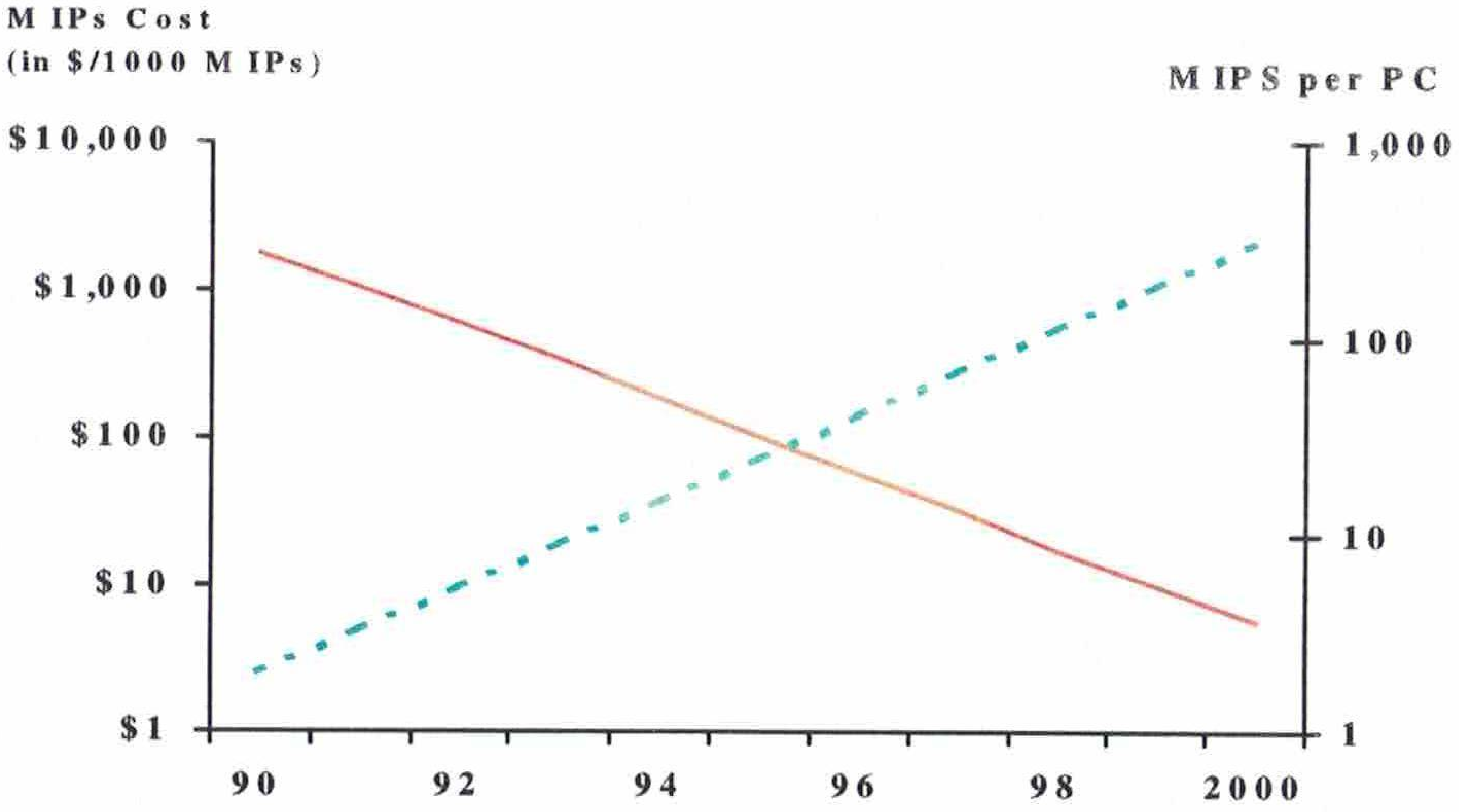
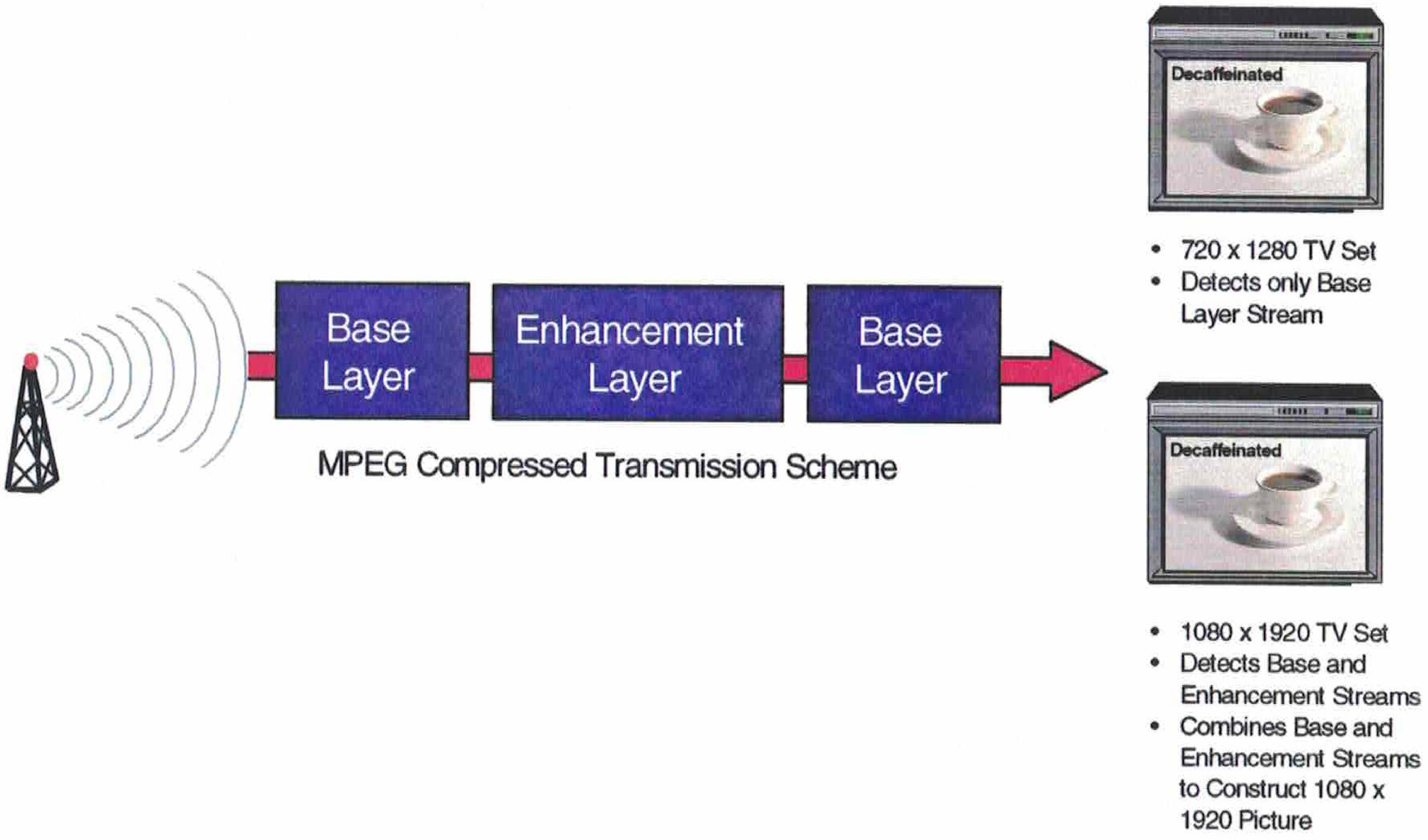


Figure 1: Moore's Law Illustration

To allow for a gradual migration, the computer industry is proposing a "layered" approach, shown in figure 6. Layering provides backward compatibility for all receivers and many types of transmission equipment, as new higher definition formats evolve.



- 720 x 1280 TV Set
- Detects only Base Layer Stream

- 1080 x 1920 TV Set
- Detects Base and Enhancement Streams
- Combines Base and Enhancement Streams to Construct 1080 x 1920 Picture

Figure 2: Conceptual Illustration of Layered DTV Formats

Additional savings available with the computer industry approach come from video programming costs. By leveraging existing WWW content and programming tools, content development costs should drop significantly from today's levels. Because of the recent explosion in Internet use, software and hardware development tools, which simplify the process of content development, are proliferating. These tools are enhancing the quality and reducing the production cost for all types of multimedia content, including graphics, audio, 3D video, as well as broadcast video.

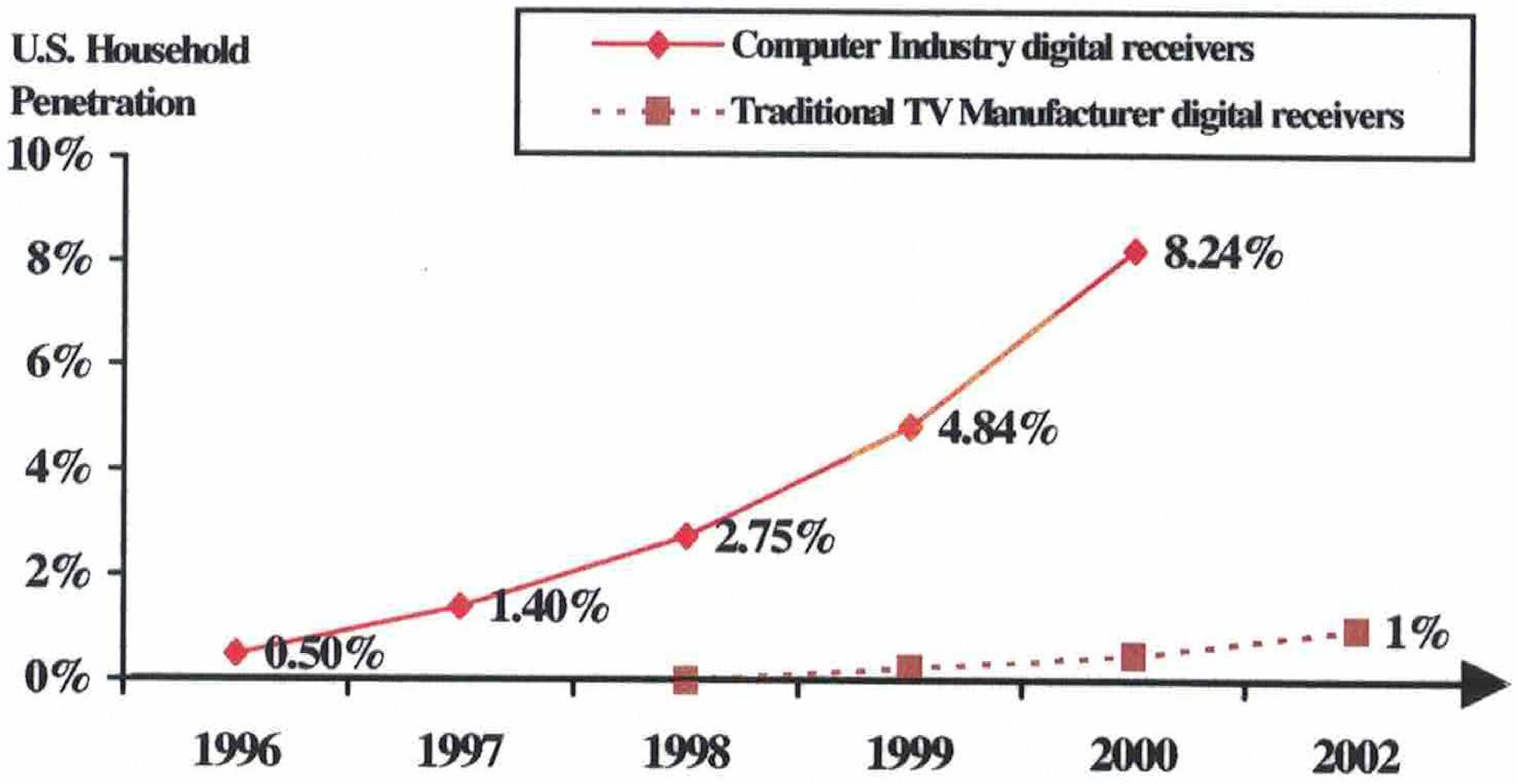
Finally, adoption of the 1080 interlace format carries significant risks for broadcasters for two primary reasons. First, many current advocates of interlace concede that the future of broadcasting will be progressive. Given this, the more efficient path would clearly be to commit to progressive today. The prospect of making two investments – investing in interlace today and then upgrading to progressive in the future -- is simply not viable.

Secondly, by committing to interlace, broadcasters will be relegated to an inferior, passive entertainment offering. The risk exists that some other party will fill the void left open by broadcasters with a richer, more interactive entertainment offering. Under this scenario, broadcasters would not only have made a large investment in interlace, but they would be forced to make an additional investment to convert to a progressive scan format. The Digital TV team approach grants broadcasters with a far superior competitive position as providers of the most compelling viewing entertainment experience.

4. Larger Audiences for Digital Broadcasts

When broadcasters make their conversion to digital, the number of viewers able to receive this signal will be far greater with progressive scan. Quite simply, the TV manufacturer's approach relies on expensive receiving devices that will not be affordable to the majority of viewers. The Digital TV team approach leverages the existing installed PC base and promises the introduction of new, less expensive devices to receive digital transmission.

Adoption rates for digital receiving devices are notably different under the two plans. The TV manufacturers project a market penetration for their digital televisions of just 1% by the year 2002. The computer industry promises to have far greater penetration (more than 20 million homes by the year 2002) from primarily two types of products: PCs with TV tuners and new, lower cost DTV appliances designed for the consumer market to support Web and broadcast programming. These DTV appliances will look and operate much like today's TVs but they will be more genetically similar to the PC.[1] No forecasts for DTV appliances exist, but the adoption of PCs with TV tuners alone far exceeds the rate projected by TV manufacturers for their products, as shown below.



Source: Grand Alliance Estimates, Dataquest

Figure 3: Estimated American Household Penetration of DTV Products

Cost is the primary driver of the different acceptance rates. Digital TV tuner cards which enable existing PCs to receive broadcast DTV signals for a PC are projected to cost about $100. On the other hand, new DTV products, which require a receiver, computer processor, memory, and a display system, cost several thousand dollars. The compatibility with the installed base of computers in residential homes is critical for achieving rapid market penetration.

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[1] DTV appliances likely to include full web capabilities but will likely not include file storage, multiple software applications and other PC capabilities.

Furthermore, the cost for a standalone DTV receiver/display product is greater for the traditional TV manufacturers' proposal. The chart (Figure 8) below breaks down costs into the two components of a digital TV: the receiver and a display device. For the TV manufacturers, receiver costs are higher due to the greater memory and processing required receiving 18 video formats and the higher 1080 line resolution. Additionally, once vested in 1080 resolution, the TV manufacturers commit to very large display devices since the larger screens are required for viewers to perceive their higher resolution images. Display devices capable of resolving 1080 x 1920 lines of resolution are extremely high end --- this is not the "Sweet spot" of the market. Conversely, the receiving devices are lower cost under the Digital TV team plan with lower, 480 and 720 line resolution. The Digital TV team approach supports a broad range of display devices ranging from as low as 13" to as high as 54." This range of products and corresponding price points enables the computer industry to tap into a broader market.

	ATSC Specified TV Set	**DTV Team Specified TV Set**
Receiver Costs	$319	$106
Display Costs - Monitor range (13" to 54")	NA - $2,149	$162 - $2,149
TOTAL	$2,468	$268 - $2,255

Source: EIA, Economics and Technology, Inc.

Figure 4: Comparison of retail prices to consumers

The TV industry will be making a substantial commitment to convert to digital. Once broadcasters have made this investment, they will be dependent on receiving devices to achieve financial returns. By their own estimates, the TV manufacturers' penetration rate is simply not attractive. Only with the Digital TV team approach can digital broadcasting reach a critical mass of American homes to realize timely returns.

Summary of Economic Review

Clearly the TV industry's financial outlook and strategic position depend greatly on its decision regarding video display formats. The vision of the future and the prospects for exciting new revenue opportunities make the computer industry approach dramatically more compelling. Additionally, broadcasters will need to invest far less, undertake fewer risks and realize faster returns on their investments working with the Digital TV team.

Only with the computer industry approach can the TV industry grasp the full range of opportunities from digital TV.

This paper now moves into a very different discussion. The section above primarily focused on the economics of digital TV. At this point, we now provide an overview of the computer industry's technical proposal for digital TV. The first section addressed *why* the TV industry should adopt the Digital TV team's approach; the second section begins the dialogue of *how* the TV industry should migrate technologically.

Technical Overview – Digital TV Team Recommendation

This proposal is described in four parts: (1) key characteristics and objectives; (2) initial digital implementation; (3) future upgrades and (4) next steps on the road to digital television. The purpose of this proposal is to begin the process of taking widely-discussed concepts and converting them into a concrete plan to make digital TV a reality. A complete technical description of this approach will be provided in PC '98, the computer industry's *de facto* specification for computer capabilities.

1. Key Characteristics and Objectives

In developing this technical proposal, the digital TV team focused on meeting both the objectives of the TV industry and the needs of viewers. Much of the rationale for the proposal was described in the first section of this paper; nevertheless, the following represents key principles of the Digital TV team approach.

- Provision of high definition picture quality
- Leverage of previous digital TV standards work
- Support for progressive scan
- Support for a wide range of receiver devices at different price points
- Cost effective migration for future enhancements

With these elements in place, the TV industry should be able to achieve the economic gains described in the previous section and viewers will be able to benefit from the broadest, most fulfilling entertainment offerings in a timely manner.

2. Initial Implementation – High Definition Television

The plan for initial digital implementation incorporates several of the above characteristics. First, the proposal leverages previous standards work by adopting a practical subset of the broad range of Advanced Television System Committee (ATSC) DTV video format combinations. The table below indicates the specific formats supported for initial implementation.

Vertical Lines	Horizontal Lines	Aspect Ratio	Picture Rate
720	1280	16:9	24P
480	704	16:9 and 4:3	60P, 60I, 30P, 24P

Table 4 Digital TV Team's High Definition Formats

This specification defines the minimum requirements for all future DTV reception products. Other dimensions (not shown above) of the specification for digital TV formats are unchanged from the original ATSC definition.

These formats will provide higher quality images than today's standards (using 525 interlaced scanning and NTSC encoding). The recommended broadcast standard for most live sports, news, and mainstream programming is 480 x 704 lines with 60 frames per second (fps) using progressive scan, providing twice the temporal resolution (for fast moving scenes) and highly enhanced (line flicker free) spatial resolution for text and other stationary images.

Second, the proposed formats are progressive scan. As described in the first section, progressive enables the integration of WWW and Internet infrastructure with traditional broadcast services. This allows access to the burgeoning repository of information and entertainment on the Internet which is progressive scan. Also, progressive displays much higher quality static graphic images than does interlace scan. The range of fonts and the capacity for displaying graphics are far superior with progressive.

The proposal includes just one exception for interlace scan. A 480x704 line resolution, a 60fps video format with interlace scanning is required to support existing legacy systems and environments where analog NTSC signals are present. Computation and memory capacity is available in DTV receivers to support interlace conversion requirements at this low resolution.

Third, the proposed DTV formats will be easily received and displayed by a broad range of receiving devices at different price points. Today's PCs will be compatible immediately with the formats using an optional DTV tuner card. DTV broadcasts will be received on future consumer (small screens) and entertainment (large screens) PCs and Digital TVs (receiver and monitor only) using dedicated video decompression hardware. However, its is expected that reception and decompression of DTV signals would be accomplished in PC software by the year 2000.

Finally, video production equipment exists today to support the recommended DTV formats. For example, 525 line progressive cameras are commercially available today from leading suppliers; 1080 line interlace cameras are not projected to be available for some time. The Digital TV team's approach leverages existing equipment rather than betting on the future development on new equipment.

3. Future Upgrades

The strategy for advancing to higher resolutions is to migrate at a cost effective pace, consistent with advances in technology. As described in the economic section, broadcasters would make their investments in a schedule consistent with the technical evolution of digital receiving devices. This gradual approach will take advantage of Moore's Law, which indicates that digital signal processing and memory capabilities double every 18 months without an increase in cost. The Digital TV team proposes a layering approach to allow a time-phased migration up to very high, progressive resolutions.

Video "layering" is the proposed approach to support a smooth migration to higher resolutions. With layering, higher resolution video information is transmitted in the same channel as lower resolution video without causing interference to legacy reception equipment. Legacy receivers, capable of receiving lower resolution video, simply ignore higher resolution video information. New receivers, capable of higher resolution reception, combine lower and higher resolution video information to reconstruct the original higher resolution video stream. Thus, all existing reception equipment would be capable of receiving any enhanced broadcast video because of the backward compatibility offered by layering; however, legacy equipment might be limited to display of lower resolution signals only. Layering is not initially specified in the computer industry's proposed DTV formats. Instead, the layering method will be fully specified in the future as higher resolution formats become defined and cost-effective.

The first extension to the initially recommended DTV formats would offer support for two additional DTV formats: a 720 x 1280 line, 60 fps, progressive scan format to provide reception capacity for cameras currently under development by major production equipment manufacturers; and a 1080 x 1920 line, 24 fps, progressive scan format to accommodate future very high resolution film media. This extension layer would be implemented in the year 2000, in time to provide reception capacity for projected availability of higher resolution broadcast equipment.

Vertical Lines	Horizontal Lines	Aspect Ratio	Picture Rate
1080	1920	16:9	24P
720	1280	16:9	60P

Table 5: Computer Industry's First Enhancement Layer to Initial DTV Formats

4. Next Steps

Additional details of the Digital TV team's technical approach will be communicated shortly. Included in these plans will be a complete specification for DTV formats and compression and transmission methods that the computer industry can economically support in the near term. The plans will be released as part of the PC'98 specification that will be concluded at the annual Windows Hardware Engineering Conference (WinHEC).

The worldwide PC industry comes together each year at WinHEC to present and discuss the specifications for capabilities that will be *de facto* standards in the next year's PC. Notably, this year there will be a recommended specification for Digital TV reception capability as part of the baseline capability of all consumer (small screens) and entertainment (large screen) PCs that will be produced next year. While implementation of these recommendations is completely voluntary on the part of the PC manufacturers, experience has shown that virtually all PCs rapidly converge around these specifications, creating worldwide *de facto* standards.

The Digital TV team is moving forward. Compaq will produce complete systems that will adhere to the PC98 *de facto* digital video standards. Further, Compaq has disclosed that it intends to produce "TV/PCs" that combine the best features of both television and PC entertainment. Microsoft has committed to provide platform software to support these specifications at both the full PC and appliance levels. Intel also has agreed to provide leadership in this regard by producing subsystems that conform to these specifications. The Digital TV team has a long history of working together to provide compelling products.

Conclusions

The advent of a new, digital era presents the TV industry with significant opportunity. But this opportunity depends on the industry's selection of video display formats. This paper is the first in a series explaining the importance of this decision and a bold new vision of the future. But the purpose of this paper is not to launch a one-way campaign; rather, the objective is to begin a dialogue that will enable the television industry and the growing Digital TV team to work together in defining the future of entertainment. Together, we can shape an exciting vision; we can integrate the best of information, entertainment and broadcast services. We can capture the full potential of digital television.

Broadcast Pipeline & Technical Recommendations

The Digital TV Team believes that its approach to enhanced digital television offers new revenue streams to broadcasters, new content opportunities for producers, and a rich new entertainment experience for consumers.

The production of broadcast content can be divided into a series of stages:

- Content Creation
- Capture
- Archiving
- Production
- Transmission
- Reception
- Display
- Viewer Experience

The Digital TV Team proposal for video formats directly affects the Transmission and Reception stages only. Our proposal leaves producers choices at the earliest stages, though we do make some recommendations in these areas.

Transmission

The Digital TV Team advocates a staged approach to the introduction of high-definition television, matched to available and affordable decoding and display technology that will enable a rapid transition to a family of high-definition formats, up to 1920 x 1080, 60 Hz progressive, and potentially beyond.

We propose a dual mode base layer format that uses higher definition 1280 x 720, 24 Hz progressive format for film-sourced material (movies or prime time shows), without B-frames or 704 x 480, 60 Hz progressive scan with B-frames for live video capture. 1280 x 720 will be perceived as almost identical to 1920 x 1080 on almost all consumer displays available in the near term, and is still quite a leap over what is available currently even in the finest, present day, digital TV studios using ITU-601.

This dual-mode base layer, which we will call High-definition Digital Television Level 0 (HD0), is derived from two of the ATSC formats. To achieve this we will use MPEG encoding and decoding at 2 times the normal rate of MPEG-2 MP@ML.

HD0 would consume approximately 9.5 Mbits/sec from the channel, or roughly 50% of the terrestrial broadcast channel capacity.

It is important to note that this dual mode base layer allows true high definition transmission and display, especially from film-based materials, and does not require the agreement on, or introduction of the first enhancement layers, in the initial products in 1998. Due to the lack of availability of either 720P or true 1080I cameras in production quantities for most of 1998, we expect that most initial HD0 programming would be film-based anyway. It is current practice to use film for the production of most prime time programming now as well.

With the addition of the enhancement layers in the future, each of the modes can be stepped up to a higher level of resolution, yielding 720P60 for live action and 1080P24 for film. Un-enhanced receivers would still recognize the HD0 portion of the signal. We would refer to this as High-definition Digital Television Level 1 (HD1). Even this would leave roughly 10% of the 8VSB channel for data and enhanced TV applications. We would expect the introduction of this level to be deemed economical and corresponding with improved consumer display technologies probably in 1999 or 2000.

It is possible that further algorithmic improvements could yield HD2, resulting in 1080P60 for live action and film resolutions at an even higher level of resolution. Certainly this is possible in channels with intrinsic bit-rates beyond those at the limit of 8VSB in a 6MHz channel, for example in 256QAM modulated cable systems, or higher rate satellite, or terrestrial systems with wider channels or different modulation standards. This level is likely to correspond to economically available large screen consumer display technologies that are available in the 2001 and beyond timeframe.

Finally, we would propose to use the newly evolving standards for IP multicasting, which have emerged from the Internet to support data broadcasting. These are carried within the MPEG transport stream, which per the FCC Rule and Order with further Rulemaking by the FCC, can be used for these purposes. We plan to use them to provide more sophisticated compression techniques such as MPEG4 and Bilinear Motion Compensation to achieve HD1 and higher level television services. We will also use this to provide enhanced forms of broadcast television programs at various video resolutions, and for other data services such as low-bit rate video and other types of information services which can be delivered in real time or delivered to systems containing local storage for subsequent consumption. These types of services are already operational on the Internet, on Satellites and with VBI in existing analog television transports today.

Reception

The DTV Team proposal uses MPEG encoding and decoding at twice the normal rate of MPEG-2 MP@ML. These decoder chips are simpler and less costly than the decoders being designed now for the ATSC specification MPEG-2 MP@HL, and are a natural byproduct this year of shrinking the implementations of the prototype decoders and the movement to use SDRAM memory in concert with these parts. (Encoders for this dual layer system can also be produced more easily and will be available in time for introduction of services in 1998.) Further, by only using B-frames in the compression of the live-action digital camera materials we can reduce the MPEG decompression memory requirement from 6MB to 2MB, lowering the cost of the first generation receivers.

The maximum output rate needed for the HD0 live video format is 20.28 MegaPixels/sec, and it requires 2 Mbytes of decode memory. The HD0 film format (720 p 24) has a maximum output rate is 22.12 MegaPixels/sec, and decoder memory is comfortably under 4 Mbytes. The HD1 enhancement decoder has 8 MB and runs 56 MegaPixels/sec. HD2 will require a 124 MegaPixels/sec and 16 MB decoder.

The Digital TV Team thus believes that progressive scan transmission will lead to cheaper receivers, since an interlaced broadcast signal would have to be de-interlaced before being combined with locally generated text and graphics. If a signal is broadcast in interlace format, each receiver will require having either a very expensive or a low quality de-interlacer.

One of the greatest barriers to consumer acceptance of new technology is the fear of obsolescence. The Digital TV Team's layered architecture guarantees that consumers can purchase receivers immediately in the knowledge that they will not become obsolete if or when broadcasters go to higher resolutions. HD0 receivers will continue to work even when decoding HD1 or higher broadcasts, though of course only the lowest level quality will be displayed.

The Digital TV Team's goal is that both TVs and PCs are available as receivers from the beginning. We believe that the PC industry offers a significant opportunity to ramp up the number of DTV receivers rapidly. The Team is working to ensure that base layer DTV decoders will be a standard part of consumer PCs shipped in 1998. Further, "PC98" will *only* decode the video formats described above, not other formats in the ATSC standard. Consumer PC sales in 1998 are forecast to be approximately 15 million units. There will thus be a significant number of PC receivers ready to decode HD0 DTV signals in 1998. Interlace broadcasts will not be received by this rapidly growing audience.

Other stages in the pipeline

Content Creation

Digital television will lead to the creation of three kinds of content: traditional, linear narratives; video narratives enhanced by optional interactivity; and new data services such as multi-media magazines broadcast for use at a viewer's leisure and on-demand video broadcast on the Internet.

Digital broadcasting will offer the consumer a combination of video, audio, and Web data. Data-enriched programs use information broadcast in parallel with the video signal to add to the viewers enjoyment by offering games, gossip and backstory angles and the opportunity to chat on-line with other fans. It allows producers to build viewer loyalty in new ways, and to pursue new revenue opportunities. For example, news-oriented shows can dramatically increase their information content by combining simultaneous broadcast of video and Web data.

Digital Broadcasting will offer the consumer a wealth of new services. The Web and the PC have proven that instant, on-demand access to critical news and information resonates with the consumer. Personalized information delivery such as daily delivery of personalized news is already popular on the Web, and will likely be enhanced and delivered on both TVs and PCs in the future.

The most valuable incremental revenue streams derive from enhanced programming and new services, which are dependent on the provision of data services as an integral part of the broadcast architecture. Enhanced TV thus consists of Video **plus** Data. The Digital TV Team specification by design allows a substantial data stream to be broadcast along with the video signal, opening up these new revenue opportunities.

The entertainment industry is already active in producing “data plus video” entertainment. An increasing number of web sites are adding video to their pages, and network producers are working with the software industry to add interactivity to existing broadcast television shows using new tools such as the Microsoft Broadcast Architecture.

Data enhancements to broadcast shows can be created using standard web authoring tools. Staff working on this content can be easily integrated with the rest of the production team throughout the shooting process. Enhancements are conceived and designed to complement the plot as it is created, and are combined with the video stream at transmission time.

Production

In general, we recommend that production be done in the highest-resolution, progressive-scan camera formats, which are economically available. We believe that production cameras will be available in 720P and 1080I in roughly the same timeframe in 1998. Early HD0 services can be based exclusively on film-sourced content, with the phased introduction of live action materials, as the cameras become more widely available. Small broadcasters can utilize the already-available 480P cameras to originate studio and field programs at a reduced expense, but with significantly better picture quality than current NTSC systems. If production is preferred in the 1080I format, this can be filtered down very effectively to the 480P60 live-action base layer, and reasonably well to the 720P60 level for HD1. The advanced bilinear motion compensation techniques which we anticipate using in the enhancement layer encoding may be more effective operating from the progressively-scanned source material or archival materials, so we recommend that progressive scanning be used in cameras at the earliest possible date. Tape recording equipment is already available for all of these formats at this time.

Capturing content at the highest-possible progressive scan format also provides the best way to store material for future use.

The migration to digital television will require a major re-engineering of existing studio, production and post-production facilities as a result of moving to higher resolutions and bandwidths. This process will have to take place regardless of the capture or transmission format used. The Digital TV Team believes that while interlace-based production methods may be attractive as an interim approach in some cases, a progressive scan approach is the most advantageous in the long run.

Display

There is a wide variety of display technologies to choose from, from Cathode Ray Tubes (CRTs) to plasma displays. Computer CRT displays transitioned to progressive scan more than 15 years ago due to severe problems with display of fine detail on interlaced monitors. Computer monitors are also already high definition compared to TV sets, and have been so for a long time. Newer display technologies, such as LCD's, Digital Mirror Displays (DMD), plasma, etc. are all inherently progressive scan devices. Interlaced scan formats are a relic of the earliest mechanically scanned television systems, and are really only effective when used with an interlaced display -- the only kind of interlaced display that exists is the CRT.

Viewer Experience

Integrated program guides will be key component of the digital television experience. The rich graphical user interfaces afforded by the underlying computing power of the new generation of smart TVs (and PCs, of course!) will create a uniform way for viewers to find and consume entertainment across all their entertainment devices. An integrated program guide will combine the shows available from broadcast services you subscribe to with those on your personal devices like a DVD player. You could find a movie by picking from a single list that combines discs you own with shows scheduled for broadcast. Computing also offers users the option of enhancing their viewing. For example, you could subscribe to additional camera angles of a sports game delivered via low bit rate video on a broadcast data stream. The sportscasters will still do most of the work to create a seamless afternoon's entertainment, but you could switch to Quarterback Cam if you wanted to look inside the huddle.